The vulnerability of karst springs – a case study of the Hubelj spring (SW Slovenia)

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Abstract: The hydraulic behavior of a karst aquifer in the Hubelj spring catchment area (SW Slovenia) was studied by using a three-component hydrograph separation technique basing on natural tracers. The results produced information on the aquifer recharge, storage and discharge processes, as well as on mechanisms that affected them.

Key words: karst aquifer, hydraulic behaviour, natural tracers, three-component hydrograph separation technique

Introduction

The groundwater of karst aquifers is becoming an increasingly important source of water supply in many countries, Slovenia included. In order to protect the karst water from pollution and overexploitation the research project, focusing on behaviour investigations of a karst aquifer in the catchment area of the Hubelj spring (Figure 1), was performed.
The Hubelj spring catchment area is a high karstic plateau Trnovski gozd that consists mainly of the Jurassic limestones[1] and occupies 50-80 km^2 [2] (Figure 1). The study area was investigated by the natural tracer research method that based on the sampling performed in two stage: a) the long-term sampling in monthly intervals, for establishing base

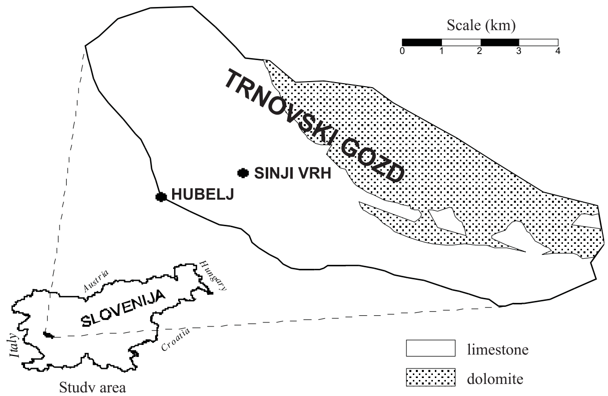

Figure 1. Location of the study area

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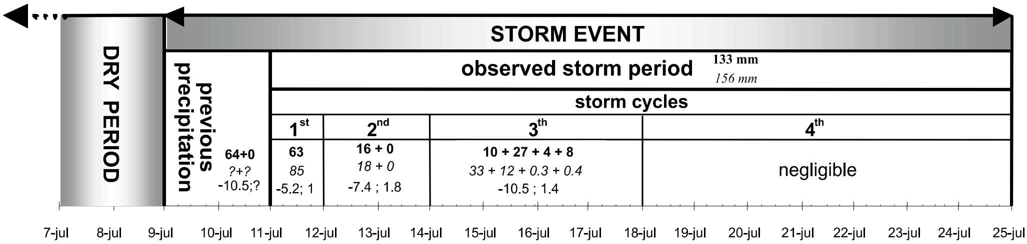
flow characteristics and b) the short-term sampling during the storm event, for identifying the karst aquifer discharge response to the summer storm event.

The short-term monitoring of the precipitation and karst system water (the upper unsaturated zone and spring water) during the storm event in July 2000 (presented in Figure 2) is stressed in this paper. This monitoring produced data for a three-component hydrograph separation technique[3], [4], [5]. The variations of natural tracers, the oxygen stable isotopic ($\delta^{18}O$) and dissolved organic carbon (DOC) composition, enabled to separate the storm hydrograph of the Hubelj spring into the following end members: a) the event water, b) the upper unsaturated zone water (soil +epikarstic water), and c) the base flow water (phreatic + lower unsaturated zone water) component.



10 + 17 precipitation amount (mm) in the catchment area of the Hubelj spring
33 + 12 precipitation amount (mm) at Sinji vrh
-7.4; 1.8 mean $\delta^{18}O$ (‰) and DOC (mg/l) composition of precipitation

Figure 2. Presentation of the storm event in July 2000

RESULTS AND DISCUSSION

The karst systems response to the summer storm event was studied from 11 to 25 July 2000 in the so-called observed storm period (Figure 2). The precipitation amounts and discharge measurements of the Hubelj spring are illustrated in Figures 2 and 3.

The first storm cycle was the most important part of the event (Figures 2 and 3). It resulted in an increase of the Hubelj spring discharge from 0.6 to 24 m^3/s (Figure 3). The following storm cycles did not influence the spring discharge so much, as well as the previous precipitation (Figures 3). Although the amount of the previous precipitation was even somewhat greater from that one of the first storm cycle (Figures 2 and 3), they resulted in just a slight increase of the Hubelj spring discharge (from 0.4 to 1.8 m^3/s). This precipitation had an insignificant impact on the saturated zone, because the $\delta^{18}O$ and DOC composition of the Hubelj spring reached again base flow values before the observed storm period. This information indicates that the previous precipitation mainly resulted in the aquifer recharge and storage processes, while, in contrast to the observed storm period, the discharge process was not typical[5].

The Hubelj spring $\delta^{18}O$ and DOC composition of the observed storm period is illustrated in Figure 4. The presented data were used for the three-component separation of the Hubelj spring storm hydrograph. The results indicated that the role of the upper unsaturated zone in the aquifers behavior had to be studied[5], [6]. Therefore, the so-colled epikarst hypothesis was tested[7], [8]. It presumes that an important part of the karst aquifer recharge arrives, rapidly and in concentrated form, from the epikarst zone. According to the epikarst hypothesis it was examined whether it is possible to combine the event and upper unsaturated zone water components into one component, an epiflow[9] component, representing the fast flow that arrives from the epikarst zone. The hydrograph separation into a) the base flow and b) the epiflow component was much more realistic. The results are presented in Figure 5. It could be noted that there was the epiflow breakthrough at the very beginning of the hydrograph concentration, which resulted in the inversion of the hydaulic gradient. Hence, the recharge had been tied to the karst conduit network during the hydrograph concentration and only the base flow component had been discharged in the spring. The epiflow component began to increase in the initial hydrograph recession. This component reached the maximum portion (84 %) at the end of the first storm cycle. Afterwards it had mostly decreased and reached a negative value on 21 July, when the inversion of the hydraulic gradient occurred again. Hence, there was only the diffuse recharge process in the aquifer from then, and only the base flow recharge the Hubelj spring.

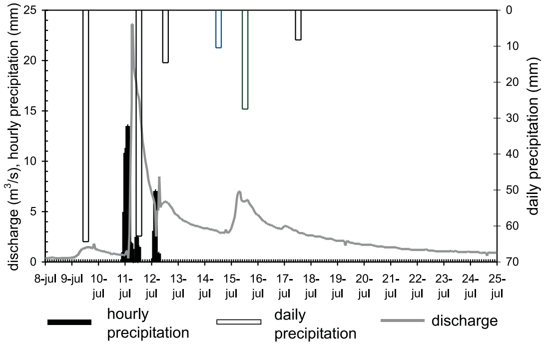


Figure 3. Daily precipitation, hourly precipitation and the Hubelj spring discharge

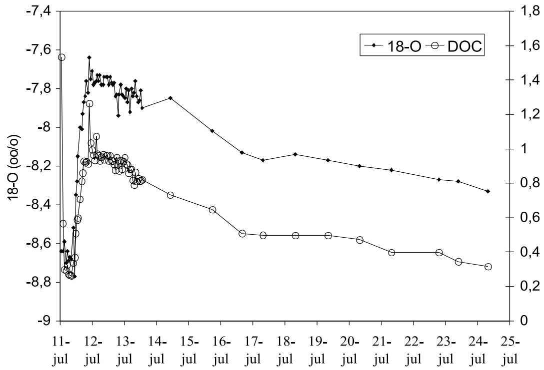


Figure 4. $\delta^{18}O$ and DOC composition of the Hubelj spring

The average contribution of the epiflow component to the Hubelj spring storm discharge was 48 % during the first two storm cycles (containing 31 % of the event water and 69 % of the upper unsaturated zone water on average), while it was 41 % during the observed storm period respectively (containing 54 % of the event water and 46 % of the upper unsaturated zone water on average).

CONCLUSIONS

The presented results indicated a) the prevailing types of flow during a certain part of the hydrograph (either fast or diffuse), b) the contributions of karst aquifer zones in a summer storm flow generation, and c) the role of the upper unsaturated zone water in the karst aquifer behaviour. They provide an insight into the aquifer recharge, storage and discharge processes, as well as on mechanisms that affected them. These data could contribute not only to the scientific understanding of the phenomenon but also to its application. If the hydraulic behaviour of the karst aquifer is adequately understood, then also efficacious characterisation and monitoring strategies for sustainable water management could be recommended.

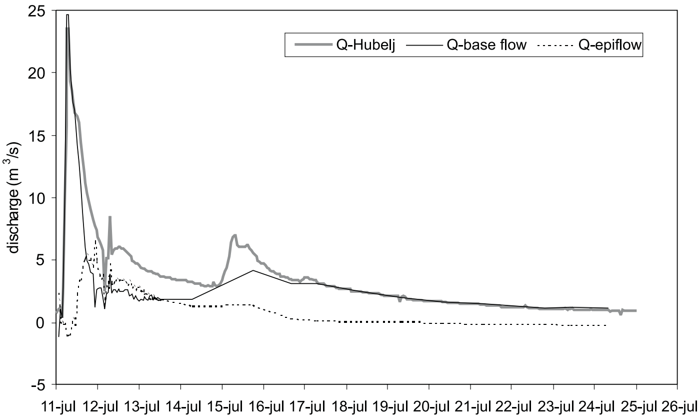


Figure 5. Hydrograph separation of the Hubelj spring

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